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PATENT ABSTRACTS OF JAPAN

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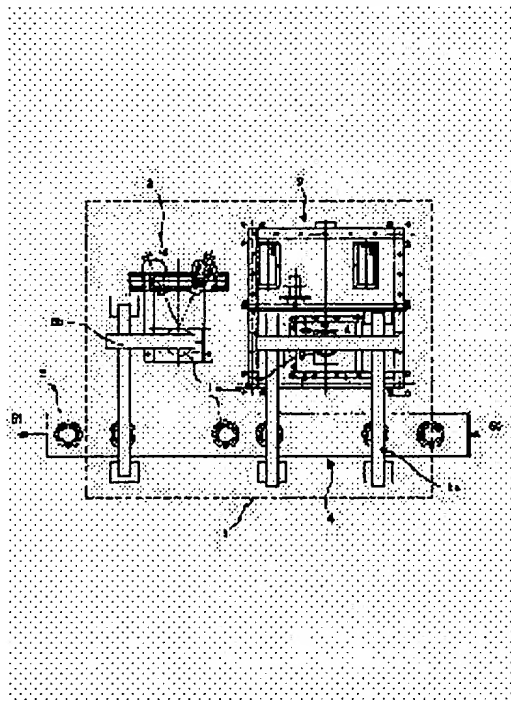
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OCHIAI MASANORI**(54) APPARATUS FOR INSPECTING PART SURFACE HAVING U-SHAPED GROOVE****(57)Abstract:**

PROBLEM TO BE SOLVED: To make detectable a recessed defect due to a pinhole or the like without being affected by a damage generated by processing or the roughening of a substrate surface by forming a liquid film on a surface to be inspected to pick up the image thereof and processing the obtained image to judge the presence of a defect.

SOLUTION: A washing soln. is ejected to a gear while rotating the gear to remove cutting oil or the like and clean air is blown on the gear 1 to drain the washing soln. so that a predetermined amt. of the washing soln. remains on tooth surface. The gear 1 after washing is transferred to an inspection part 3 and the tooth surface is imaged to obtain an original image. Next, a differential image is formed, and succeedinglly, a smooth image reduced in noise by smoothing is formed. Thereafter, binarizing processing is performed and a recessed part is detected by the comparison with a predetermined threshold value to judge the result. All of tooth surfaces are inspected in first inspection and, when even one teeth becomes NG, air is blown to perform re-inspection. Only when all teeth become OK in second inspection, the gear is judged to be good and, when even one tooth becomes NG, the gear is judged to be inferior.



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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] It is related with suitable equipment to inspect the existence of minute crevices, such as a kennel, a pinhole, etc. which appears in the tooth flank of the gearing after processing especially, with respect to the equipment which inspects the irregularity which consists in the bill-of-materials side which has this invention and a U character-like slot by the image processing.

[0002]

[Description of the Prior Art] The gearing generally widely used as components, such as a machinery, has many which fabricate by forging, or process rolled stock, and are manufactured. On the other hand, the gearing made from a casting with the big damping effectiveness is also used for mechanical vibration or a noise reduction. When internal openings, such as a kennel peculiar to a casting and a pinhole, remain, they may expose this casting gearing to a front face as a hollow after tooth flank processing. When such a gearing is used for a power transmission device, while in use, destruction progresses gradually from the hole and destruction of a gearing and a machinery may be caused also in an about [$\phi 0.1\text{mm}$] very small hole, for example. for this reason, the crevice appeared on the front face -- high degree of accuracy -- dependability -- detecting highly becomes important.

[0003] the probe which consists of a sensing coil although there is eddy current flaw detection as an approach of detecting a defect with a minute front face -- a control surface -- receiving -- uniformly -- or -- ** -- it is important to scan by the fixed lift off (distance of a control surface and a probe). However, detection is [that the distance of a probe and a control surface tends to change] difficult when a control surface has a curved surface. JP,59-218946,A is indicated as an approach of solving this (well-known example 1). This is scanning a control surface using the probe which carries out flaw detection of the front face of the analyte which becomes the complicated three-dimensions-configuration of a wave front face like bellows, or others, has ***** of the same configuration adapted to the configuration of a control surface as shown in drawing 9 for the purpose of detecting the defect of the front face and near to high degree of accuracy, and has arranged two or more vortex sensors, and is the approach of inspecting the curved-surface section at once. On the other hand, the dent distinction approach of a gear of having used the image processing is indicated by JP,63-201556,A (well-known example 2). As shown in drawing 10, this rotates a gear by the motor and illuminates at least the Banking Inspection Department with a lighting system. It is the approach of incorporating at least the Banking Inspection Department as an image with image pick-up equipment, evaluating the brightness of the obtained image, and distinguishing existence, such as a dent of a gear tooth flank. Two or more images from the same are created on the real target about a tooth flank which picturizes a different gear tooth flank from the gear tooth flank which should set and inspect predetermined spacing, and its tooth flank, and is different. The subtraction image which compares mutually the image of a different gear tooth flank from the image and tooth flank of the gear tooth flank which should be inspected, and expresses the difference of the brightness between the image is created. It is the approach of distinguishing the existence of a dent by adding this subtraction image, creating an addition image, and comparing the brightness of this

addition image with a predetermined brightness reference value.

[0004]

[Problem(s) to be Solved by the Invention] However, in a well-known example 1, since the machine device for scanning a probe is needed, in a gear with many numbers of teeth, it is difficult [it] to shorten inspection time amount. Furthermore, in order to detect an about 0.1mm minute defect, it is necessary to arrange a minute vortex sensor precisely, and there is a problem of causing complication of a machine and low dependability-ization. Moreover, in a well-known example 2, extraordinary high degree of accuracy is required of positioning of the gear control surface in an image image pick-up for the comparison with a criteria image. Moreover, when dry areas by processing, such as a blemish and a pattern, exist in a control surface, since these change with each tooth flanks, they have a possibility of also incorrect-detecting these dry areas and a lay as a defect with a defect. The object of this invention is to offer the approach and equipment which detect the concave defect by the irregularity which exists in the front face of the components which have a tooth form configuration, especially a shrinkage cavity, a pinhole which are exposed to a front face after processing of a tooth flank, etc., without being influenced by the dry area of substrate sides, such as a minute blemish produced by processing, and a lay.

[0005]

[Means for Solving the Problem] The attaching part which carries out positioning maintenance of the inspected object with which this invention formed liquid membrane in the inspected side, The lighting means arranged so that light may be irradiated along the tool feed direction at the time of inspected side processing in an inspected side, It is characterized by having the image pick-up means arranged so that the scattered reflection light of exposure light might carry out incidence while the image pick-up shaft countered this inspected side, and the image-processing section which processes the image from an image pick-up means, and judges the existence of a defect. Moreover, U character-like slots are the components currently formed for the gear tooth which makes a tooth form configuration, and when inspected sides are two or more tooth flanks which make a tooth form configuration, said attaching part or the lighting means, and the image pick-up means are made movable so that two or more tooth flanks can be picturized serially. The attaching part which will carry out positioning maintenance of the gearing which had liquid membrane formed in a tooth flank, and will carry out revolution position control of the gearing if said component is a gearing, The lighting means arranged so that light may be irradiated from the slanting upper part at the low include angle of 30 degrees or less to the longitudinal direction in a tooth flank, It is characterized by having the Banking Inspection Department having the image pick-up means arranged so that the scattered reflection light of exposure light might carry out incidence while the image pick-up shaft countered the tooth flank, and the image-processing section which processes the image from an image pick-up means, and judges the existence of a defect. In addition, as for said liquid membrane, it is desirable that they are a non-volatile or difficulty volatility.

[0006] The supporter which uses as a gearing the components which have a U character-like slot as invention of an embodiment, and lays a gearing, A tailing means to pour out the liquid of a non-volatile or difficulty volatility on a gearing front face, a gearing front face -- said liquid -- specified quantity **** -- with the washing section equipped with a liquid end means to remove the liquid of an excess like The attaching part which carries out positioning maintenance of the gearing after washing, and carries out revolution position control of the gearing, and the lighting means arranged so that light may be irradiated from the slanting upper part at the low include angle of 30 degrees or less to the longitudinal direction in a tooth flank, It is characterized by having the Banking Inspection Department having the image pick-up means arranged so that the scattered reflection light of exposure light might carry out incidence while the image pick-up shaft countered the tooth flank, and the image-processing section which processes the image from an image pick-up means, and judges the existence of a defect. In addition, although it has the operation which the above-mentioned washing section washes a tooth flank, and it not only removes a foreign matter and dust, but carries out liquid membrane formation to a tooth flank, when a pure gearing is supplied, detergency is not necessarily required. In this case, what is necessary is just to constitute so that coating liquid may be sprayed separately and may carry out a coat to a tooth flank that what is necessary is just to give the operation which carries out liquid membrane

formation. In addition, the response is possible even if the defect mentioned above is not only a concave hole but convex adhering dirt, dust, a foreign matter, etc.

[0007]

[Embodiment of the Invention] The case where the tooth flank is inspected for a spur gear (it only abbreviates to a gear below) for an example as a gestalt of operation of this invention as components which have a U character-like slot is explained below. The top view outline of the test equipment by this invention is shown in drawing 1. It consists of the washing section 2, the Banking Inspection Department 3, the transfer section 4, and a control section (not shown) greatly. The transfer section 4 is arranged in the washing section 2 and the Banking Inspection Department 3 so that supply blowdown of the gear 1 may be carried out, and the transfer section 4 consists of the conveyor 5 and the pick & place machine 8. Moreover, in order to prevent the incorrect detection by adhering to the gear after the dust which floats in air washing, the whole is arranged all over the clean booth 6.

[0008] The outline configuration of the washing section 2 is shown in drawing 2. The gear supporter 25 is connected with a motor 26, and makes pivotable the attached gear 1. The high voltage washing nozzle 23, the rinse nozzle 24, the Ayr blow nozzle 27, and the liquid membrane formation nozzle 28 are arranged at the periphery section of a gear 1. The high voltage washing nozzle 23 injects the penetrant remover 20 of a penetrant remover tank on a gear 1 with high pressure pumping 211 through a liquid transport pump 210 and the tailing filter 220. The rinse nozzle 24 is connected with one side of piping which branched at said tailing filter 220 outlet, fills a gear 1 with the penetrant remover 20 which removed the foreign matter so much, and flushes dirt and dust which remain. The Ayr blow nozzle 27 sprays the compressed air defecated with the air filter 221 on a gear 1, and performs the liquid end. The liquid membrane formation nozzle 28 sprays the coating liquid 29 for forming the liquid membrane of the suitable amount for a tooth flank. The coating liquid 29 used for liquid membrane formation has unvolatilizing or good difficulty volatility. If aging is in the formed liquid membrane, since how a concave defect or whose lay is visible will change every moment, this is because it is unsuitable to inspection.

[0009] Liquid membrane formation besides the approach of spraying coating liquid 29 on the bottom of a suitable control condition, and performing it with the liquid membrane formation nozzle 28 as mentioned above After spraying coating liquid 29 moderately, the liquid end of the coating liquid 29 is carried out by predetermined blow time amount etc. from the Ayr blow nozzle 27. Consider as the suitable amount of coats, or Instead of coating liquid 29, a penetrant remover 20 is used as it is, and there is the approach of carrying out the liquid end of the penetrant remover 20 by predetermined blow time amount etc. from the Ayr blow nozzle 27 similarly with having mentioned above, and making it into the suitable amount of coats at the time of the liquid end of the penetrant remover mentioned above. When forming liquid membrane by the penetrant remover 20, a penetrant remover 20 needs to use unvolatilizing or the thing of difficulty volatility, and should just take the suitable liquid membrane formation approach suitably according to washing conditions etc. In addition, when the gear in the pure condition that there is neither dust nor cutting oil is supplied, a soaping-machine style is good also as unnecessary. You may prepare the Banking Inspection Department by using the optical instrument which does not need to perform liquid membrane formation at this time in the washing department, for example, is used for an image processing, and a suitable isolation means. Furthermore, when the gear in which the liquid membrane of the suitable amount for a tooth flank is formed is supplied, a liquid membrane molding machine style can also be made unnecessary.

[0010] The outline configuration of the Banking Inspection Department is shown in drawing 4 and drawing 5. A gear 1 is positioned and attached in the gear attaching part 32. The gear attaching part 32 is connected with the rotary motor 33, and can carry out revolution position control of the gear 1 held by the command of the machine control section 364. The image pick-up means 30, the lighting means 31, the Ayr blow nozzle 35, and marking equipment 34 are arranged in the periphery section of a gear 1. As shown in drawing 5 (b), the image pick-up means 30 is arranged so that the image pick-up optical axis may counter a tooth flank. Therefore, two sets are prepared so that it may correspond to two tooth flanks which make a tooth space. The tooth space is carrying out the abbreviation for U characters, or the abbreviation configuration for V characters, and this is because all tooth flanks cannot be inspected from

an one direction. In addition, one tooth flank and the tooth flank of another side have [interference of a device] the way which carries out [*****] and was picturized and are desirable instead of picturizing and inspecting the tooth flank of both which form a tooth space in the same tooth space. Moreover, if a gear is turned over and it is made to re-set after inspecting all the tooth flanks of an one direction, all tooth flanks can be picturized by one set of an image pick-up means.

[0011] As shown in drawing 5 (c), the lighting means 31 is arranged so that light may be irradiated in a tooth flank from the direction which penetrates the tooth space of a gear 1. since both tooth flanks are irradiated almost uniformly -- a bottom -- receiving -- the include angle theta of 30 or less degrees ($0 < \theta \leq 30$ degrees) -- it is good to make it become 5 degrees $\leq \theta \leq 10$ degrees preferably. What is necessary is just to arrange the lighting means 31 so that it may become the above-mentioned illuminating angle to this tooth flank when what is necessary is to picturize only one tooth flank. Thus, by arranging, since light is scattered about also in the direction of [other than angle of reflection] in the concavo-convex section to light not reaching the image pick-up means 30 since the illumination light reflects in the same angle of reflection as an incident angle in respect of there being no irregularity, light reaches the image pick-up means 30, and a concavo-convex part can be picturized. The so-called dark field image can be obtained. In addition, although a lighting means counters drawing 5 (c) in the face-width direction and being considered as two formulas, when a gear 1 is thin, it is only from one side. Moreover, there is also an approach by the light field image which illuminates from the same mostly with the image pick-up direction, regards the light reflected regularly in a control surface as another lighting, and detects irregularity. However, since it is interrupted by the front gear tooth, and light cannot be irradiated or the tooth flank is constituted from a curved surface by the whole tooth flank, there are problems -- the reflected light of uniform brightness is not obtained -- and an applicable subject of examination is limited.

[0012] Digital image transformation of the image picturized by the image pick-up means 30 is carried out in the image input section 360, and it is transmitted to the image-processing section 361. In the image-processing section 361, defective detection processing is performed by the image processing so that it may mention later, and the information is transmitted to the CC section 362. In order that the defect detected so that the tooth flank judged to be poor by the image processing might be mentioned later may reconfirm whether it is dust, the Ayr blow is carried out by the Ayr blow nozzle 35, and inspection is conducted again. The mark is put on the tooth flank section judged to be poor also in the re examination by marking equipment 34, and the result is displayed on a display 363. In addition, control panels 365 are information input means, such as the size and the number of teeth of the gear 1 to inspect, and the number, and the CC section 362 controls all processing actuation.

[0013] Next, actuation is explained. The non-inspected gear 1 is conveyed from supply side 50 by conveyor 5, and it is positioned in front of the washing section 2 according to the positioning device which is not illustrated, and is set to the gear supporter 25 of the washing section 2 by pick & place machine 8a. The washing section 2 is formed in order to remove cutting oil and cut waste at the time of processing when inspecting the gear after gear cutting or tooth flank processing. Rotating a gear 1 at a predetermined rate after that, the high-pressure penetrant remover 20 is injected from the high voltage washing nozzle 23, subsequently a lot of penetrant removers 20 are passed from the rinse nozzle 24, and cutting oil and cut waste are removed from a gear 1. Clarification Ayr is sprayed from the Ayr blow nozzle 27 under control specification, such as a predetermined pressure, a flow rate, and time amount, after that, the liquid end is carried out, and as the penetrant remover 20 of the specified quantity remains in a tooth flank, it forms liquid membrane. In addition, since it is greatly influenced by being greatly influenced by physical properties which form liquid membrane, such as viscosity of a liquid, and surface tension, i.e., the temperature and concentration of a liquid, in carrying out the coat of a suitable quantity of the liquid membrane, it is desirable to form the solution temperature regulator 201 for controlling the temperature of the liquid for liquid membrane. Although compensating automatically also about concentration is desirable, you may cope with it with checking periodically.

[0014] The cross section of the tooth flank for explaining the difference in the formation situation of the liquid membrane on a tooth flank to drawing 3 is shown. By the case where most penetrant removers are

removed, the lay 11 at the time of gear-cutting processing will be exposed as it is, and not only the crevice 10 but the lay 11 of drawing 3 (a) will be visible. Although the liquid end will be performed appropriately, a shallow level difference like a lay 11 will be filled up with the case where the liquid membrane 12 of the specified quantity is formed in a processing front face and drawing 3 (b) will be almost flat, since a crevice 10 remains, it can see only a crevice. The liquid end of drawing 3 (c) will be inadequate, a crevice 10 will also be buried with the case where liquid membrane 12 is thick, simultaneously with a lay 11, and both will disappear. Therefore, it is important for liquid membrane to form so that it may become like drawing 3 (b) according to the crevice depth made into for [of a lay 11 / of a level difference / magnitude and for detection].

[0015] After the gear 1 which finished washing is returned to the conveyor 5 for conveyance by pick & place transfer machine 8a, it is conveyed, and it is positioned in front of the Banking Inspection Department 3 according to the positioning device which is not illustrated. Subsequently, it is transferred to the Banking Inspection Department 3 by another pick & place transfer machine 8b, positioning immobilization is carried out on the gear attaching part 32, and inspection starts. The outline process of the inspection at this time is shown in drawing 7. First, in the 1st inspection, all tooth flanks are inspected by the approach of mentioning later, and the tooth flank used as NG is memorized. Since a defect may be dust when there are some which were set to NG also for one gear tooth, the Ayr blow of the tooth flank section used as NG is carried out by the Ayr blow nozzle 35, and only the tooth flank is inspected again. Since possibility of blowing away by the Ayr blow is high when the defect detected by the 1st time is dust, the probability which is not detected in inspection which is the 2nd time, but serves as O.K. is high. Only when it becomes all the gear teeth O.K., it is judged as an excellent article, when it is set to NG also for one gear tooth by the 2nd inspection, it is judged as a defective, and a mark is put on the tooth flank section by which the defect was detected with marking equipment 34. The gear 1 which ended inspection is again returned to the conveyor 5 for conveyance by pick & place machine 8b, and is discharged from blowdown side 51. Although not illustrated, the discharged gear 1 is classified by an excellent article and the defective according to the inspection result of the Banking Inspection Department.

[0016] By using an inspection method twice, as mentioned above, it becomes possible to prevent the incorrect detection by adhesion of dust etc. In addition, in the above-mentioned example, after inspecting all tooth flanks by the 1st inspection, it is considered as the approach of conducting 2nd inspection, but in the 1st inspection, if it is NG, it is good also as 1 gear-tooth deed and a method of conducting 2nd inspection immediately. As mentioned above, what is necessary is to consider as inspection once or just to set a count as the CC section 362 with the logic for a quality judging according to a required inspection specification, such as inspecting 3 times or more conversely, that what is necessary is just to determine suitably, although the inspection method was explained twice.

[0017] Next, the defective detection processing by the image processing is explained. Whenever the gear 1 transferred to the Banking Inspection Department comes to constant speed or the predetermined location where one gear tooth rotates at a time intermittently, and the image pick-up of an inspection tooth flank is attained with a rotary motor 33, a tooth flank is picturized, and inspection of a tooth flank is conducted by the image processing. Parallel irregularity is hard to be picturized although the subject-copy image (drawing 6 (a)) sent to the image-processing section 361 is the so-called dark field image which is illuminated from the low include angle and picturized the scattered light as mentioned above, and the irregularity which intersects perpendicularly with direction of incidence 31a of the illumination light is often picturized. The dental processing direction is a direction which usually meets the tooth flank, and the lay is attached to direction of incidence 31a, and parallel. Therefore, although a processing blemish shines only to a line but the part to which direction of incidence 31a and the edge section of a crevice 10 also cross at right angles often shines, a parallel part cannot shine easily. Next, level differential is performed along with direction of incidence 31a, and a differential image (drawing 6 (b)) is created. Thereby, the edge section of a concave defect is emphasized and a pattern that it is based on a lay becomes possible [weakening]. However, in differential processing, since the whole noise will also be emphasized simultaneously, the smooth image (drawing 6 (c)) which reduced the noise by smoothing is

created. Binary-ized processing is performed after that, a crevice 10 is detected by comparing with a predetermined threshold, characteristic quantity, such as area and brightness, is calculated, it judges whether it considers as a defective, and the result is outputted to the CC section 362.

[0018] as mentioned above, a thing applicable not only to the tooth flank of the narrow sense which is a dental lateral portion but the tooth crest included as a tooth flank of a wide sense and a bottom land although this invention has been explained by making into a subject of examination the crevice produced in the tooth flank of a spur gear -- obvious -- moreover, foreign matter adhesion and a dent -- being turned over -- etc. -- it can inspect also about heights. Moreover, as components which have the U character-like slot which consists of a side face fabricated by the cycloid tooth or the involute tooth, there are not only a spur gear but bevel gear, Lack, a spline, etc., and, naturally it can apply also to these. Furthermore, it cannot be overemphasized that it is applicable also to components with the shape of a rectangle and V character-like slot of the shape of a straight line like a key or a square shape spline, for example.

[0019]

[Effect of the Invention] As explained above, there is the following effectiveness in this invention.

- 1) By carrying out the coat of the optimum dose liquid to an inspected side, it is not visible, only the lay generated at the time of minute processing which is not harmful can be carried out, and it becomes possible to detect only an injurious defect and a crack.
- 2) Since it was made to inspect after washing an inspected object, cutting oil and dust after processing can be removed and improvement in dependability of inspection can be aimed at.
- 3) After washing, since it was made a soaping-machine configuration which forms liquid membrane by leaving a penetrant remover to an optimum dose front face, simplification of equipment can be attained.
- 4) Since it was made arrangement of a lighting means by which it irradiates in the direction of a U character-like slot, this scattered reflection light is picturized, and a dark field image detects irregularity, and an image pick-up means, inspection of that tooth flank is [as opposed to / the gear which has many gear teeth] possible also to a gear with a wide face width.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The top view showing the gear tooth flank test equipment which is 1 operation gestalt of this invention

[Drawing 2] Drawing showing the configuration of the washing section of the gear tooth flank test equipment shown in drawing 1.

[Drawing 3] The mimetic diagram of the crevice by the amount of liquid membrane which carries out a coat to a control surface, and a lay in which are visible to and showing the difference of the direction

[Drawing 4] Drawing showing the configuration of the Banking Inspection Department of the gear tooth flank test equipment shown in drawing 1

[Drawing 5] Drawing showing arrangement of the device for an image pick-up in the Banking Inspection Department

[Drawing 6] Drawing showing the procedure of an image processing

[Drawing 7] Drawing explaining the outline process of a 2 times inspection method of having used by this invention

[Drawing 8] Drawing explaining the conventional technique using eddy current flaw detection

[Drawing 9] Drawing explaining the configuration of the conventional technique using an image processing

[Description of Notations]

1 -- Gear 2 -- Washing section 3 -- Banking Inspection Department 4 -- Transfer section 5 -- Conveyor, 6 -- Clean booth 8 -- Pick & place machine 10 -- Crevice, 11 -- Lay 12 -- Liquid membrane 20 -- Penetrant remover 23 -- High voltage washing nozzle, 24 -- Rinse nozzle 25 -- Gear supporter 26 -- 27 A motor, 35 -- Air blow nozzle, [-- Image pick-up means / 31 -- Lighting means,] 28 -- A liquid membrane formation nozzle, 29 -- Coating liquid, 30 [210 -- Liquid transport pump 211 / 221 -- Air filter 360 / 362 -- CC section 364 -- Machine control section / -- The image input section, 361 -- Image-processing section / -- High pressure pumping 220 -- Tailing filter] 33 -- A gear revolution motor, 34 -- Marking equipment

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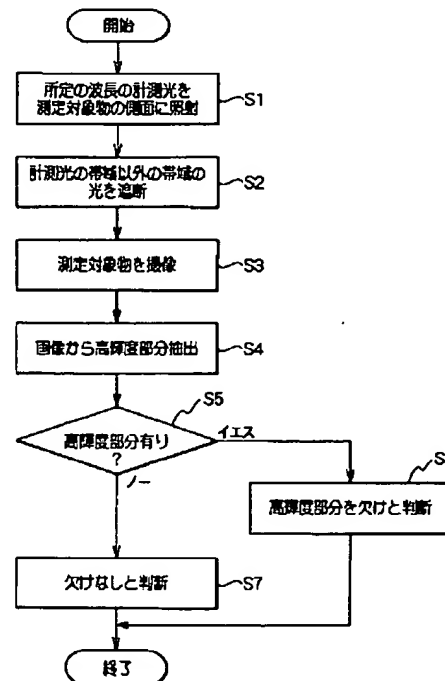
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(54) 【発明の名称】 欠陥検出方法及び欠陥検出装置

(57) 【要約】

【課題】 先端部の欠けを安定して検出すること。

【解決手段】 側面に平面を有する測定対象物の当該側面に計測光を照射する計測光照射工程 S1 と、この計測光照射工程 S1 にて計測光が照射された測定対象物の平面を撮像する撮像工程 S3 と、この撮像工程 S3 にて撮像された画像に対して画像処理を行う画像処理工程 S4 乃至 S7 とを備えている。そして、画像処理工程は、画像中に予め定められたしきい値以上の輝度を有する画素を抽出する高輝度画素抽出工程 S4 と、この高輝度画素抽出工程 S4 にて高輝度画素が抽出されたときには当該高輝度画素領域に対応する位置にて欠けが生じたと判定する欠け判定工程 S5、S6 とを備えた。



【特許請求の範囲】

【請求項1】 側面に平面を有する測定対象物の当該側面に計測光を照射する計測光照射工程と、この計測光照射工程にて計測光が照射された測定対象物の平面を撮像する撮像工程と、この撮像工程にて撮像された画像に対して画像処理を行う画像処理工程とを備え、前記画像処理工程は、前記画像中に予め定められたしきい値以上の輝度を有する画素を抽出する高輝度画素抽出工程と、この高輝度画素抽出工程にて高輝度画素が抽出されたときには当該高輝度画素領域に対応する位置にて欠けが生じたと判定する欠け判定工程とを備えたことを特徴とする欠陥検出方法。

【請求項2】 前記撮像工程の前に、前記測定対象物から入射される光の内前記計測光の帯域以外の帯域の光を遮断するフィルタ工程を備えたことを特徴とする請求項1記載の欠陥検出方法。

【請求項3】 前記欠け判定方法が、前記高輝度画素領域の画素数に基づいて当該欠陥の大きさを算出する工程を備えたことを特徴とする請求項1または2記載の欠陥検出方法。

【請求項4】 測定対象物の欠けを検出する面に略垂直な方向から計測光を照射する照射手段と、この計測光の照射方向と略直交する方向にて前記測定対象物を撮像する撮像手段と、この撮像手段によって撮像された画像に対して画像処理を行う画像処理手段とを備え、前記画像処理手段が、前記画像中に予め定められたしきい値以上の輝度を有する画素を抽出する高輝度画素抽出部と、この高輝度画素抽出部によって高輝度画素が抽出されたときには当該高輝度画素領域に対応する位置にて欠けが生じたと判定する欠け判定部とを備えたことを特徴とする欠陥検出装置。

【請求項5】 前記撮像手段と前記測定対象物との間に、前記計測光の帯域と同一の帯域の光を透過させると共に当該帯域以外の光を遮断するバンドパスフィルタを配置したことを特徴とする請求項4記載の欠陥検出装置。

【請求項6】 測定対象物の欠けを検出する複数の面に略垂直な方向から計測光を照射する照射手段と、この計測光の照射方向と略直交する方向にて前記測定対象物を撮像する撮像手段と、この撮像手段によって撮像された画像に対して画像処理を行う画像処理手段とを備え、前記画像処理手段が、前記画像中に予め定められたしきい値以上の輝度を有する画素を抽出する高輝度画素抽出部と、この高輝度画素抽出部によって高輝度画素が抽出されたときには当該高輝度画素領域に対応する位置にて欠けが生じたと判定する欠け判定部とを備えたことを特徴とする欠陥検出装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】 本発明は、欠陥検出方法およ

び欠陥検出装置に係り、特に、画像処理を用いた歯車等の工業製品の欠陥を検出する欠陥検出方法及び欠陥検出装置に関する。

【0002】

【従来の技術】 従来より、画像処理を用いた歯車等の工業製品の欠陥検査が行われている。例えば、欠陥のない良品と欠陥がある不良品の二次元画像を比較して、両者の差分を求めることで、欠陥部分を検出することができる。

【0003】

【発明が解決しようとする課題】 しかしながら、予め良品を撮像した基準画像と検査対象を撮像した画像とを比較する従来例では、厳密な位置決めが必要で、かつ環境光の変化に弱く、一方微少な傷等による判別基準以下の個体差も検出してしまい、さらに輪郭の変化しない削れなどの欠けについては安定した検出が難しい、という不都合があった。

【0004】

【発明の目的】 本発明は、係る従来例の有する不都合を改善し、特に、測定対象物の先端部の欠けを安定して検出することのできる欠陥検出方法及び欠陥検出装置を提供することを、その目的とする。

【0005】

【課題を解決するための手段】 そこで、本発明では、側面に平面を有する測定対象物の側面に計測光を照射する計測光照射工程と、この計測光照射工程にて計測光が照射された測定対象物の平面を撮像する撮像工程と、この撮像工程にて撮像された画像に対して画像処理を行う画像処理工程とを備えている。しかも、画像処理工程は、画像中に予め定められたしきい値以上の輝度を有する画素を抽出する高輝度画素抽出工程と、この高輝度画素抽出工程にて高輝度画素が抽出されたときには当該高輝度画素領域に対応する位置にて欠けが生じたと判定する欠け判定工程とを備えた、という構成を採っている。これにより前述した目的を達成しようとするものである。

【0006】 計測光照射工程では、測定対象物の側面に計測光を照射する。すると、測定対象物が良品であれば、計測光の大半は照射方向と平行な方向へ反射する。一方、当該平面部分に欠けが生じている不良品では、欠けの部分で反射した計測光は照射方向と平行な方向以外の方向へ進行する。そして、撮像工程にて、測定対象物の平面を撮像すると、欠けが生じていない場合には計測光の戻り光は撮像されない。一方、欠けが生じていると、欠け部分で反射した計測光が撮像される。続いて、高輝度画素抽出工程では、撮像した画像のうち予め定められた輝度以上に明るい高輝度部分の画素を抽出する。そして、欠け判定工程では、高輝度画素が抽出されたときには当該高輝度画素領域に対応する位置にて欠けが生じたと判定する。すなわち、測定対象物の側面の平面にて欠けが生じていると、当該欠け部分で計測光が上方へ

反射し、撮像工程にて、この欠けにて反射した計測光が撮像されるため、周囲の輝度よりも高い輝度の領域が生じる。従って、撮像した画像に高輝度画素がある場合には、測定対象物の側面の平面の一部に欠けが生じたと判定する。

【0007】

【発明の実施の形態】以下、本発明の実施の形態を図面を参照して説明する。図1は本発明の一実施形態による欠陥計測方法の構成を示すフローチャートである。図1に示すように、本実施形態による欠陥計測方法は、側面に平面を有する測定対象物の当該側面に計測光を照射する計測光照射工程S1と、この計測光照射工程S1にて計測光が照射された測定対象物の平面を撮像する撮像工程S3と、この撮像工程S3にて撮像された画像に対して画像処理を行う画像処理工程S4乃至S7とを備えている。そして、画像処理工程は、画像中に予め定められたしきい値以上の輝度を有する画素を抽出する高輝度画素抽出工程S4と、この高輝度画素抽出工程S4にて高輝度画素が抽出されたときには当該高輝度画素領域に対応する位置にて欠けが生じたと判定する欠け判定工程S5、S6とを備えている。

【0008】図2(A)は図1に示した方法の使用に好適な欠陥検出装置の構成を示す説明図である。図2

(A)に示すように、欠陥検出装置は、測定対象物Sの欠けを検出する面に略垂直な方向から計測光Rを照射する照射手段18、19と、この計測光の照射方向と略直交する方向にて測定対象物Sを撮像する撮像手段3Aと、この撮像手段3Aによって撮像された画像に対して画像処理を行う画像処理手段10とを備えている。そして、画像処理手段10が、画像中に予め定められたしきい値以上の輝度を有する画素を抽出する高輝度画素抽出部11と、この高輝度画素抽出部11によって高輝度画素が抽出されたときには当該高輝度画素領域に対応する位置にて欠けが生じたと判定する欠け判定部12とを備えている。

【0009】照射手段は、スリット光Rを照射するレーザ光源(スリット光源)18と、このレーザ光を測定対象物の側面へ走査するガルバノスキャナ19とを備えている。従って、「欠けを検出する面に略垂直な方向」は、当該ガルバノスキャナ19により走査される時の走査開始位置から走査終了までの角度を含む。図2

(A)に示すように、測定対象物Sに欠け2a、2bが生じているとき、この測定対象物の側面に計測光を照射すると、欠け部分2a、2bによって反射した光は垂直方向のCCDカメラ3aに入射する。すると、この入射した部分の画素は、図2(B)に示すように高輝度画素となる。このため、画像20に高輝度画素が含まれているか否かによって、測定対象物側面に欠けが生じているか否かを判定することができる。

【0010】図3は歯車などの鋳物や焼結品の刃先の欠

け等の例を示す説明図である。図3(A)は良品の一例を示す図で、図3(B)及び図3(C)は欠け25、27が生じた例を示す図である。図3(B)に示すように、測定対象物24の刃先の全体に欠け25が生じた場合には、符号15で示す観測方向から撮像することで、測定対象物の外形の変化を検出することができる。しかし、図3(C)に示すように、測定対象物26の刃先にて符号27で示すような欠け27が生じると、良品とは異なった傾きの面が生じる。このとき、図3中の観測方向15からの撮影では、欠陥部分の検出が難しい。このため、本実施形態では、面の傾きの違いを利用して欠陥の検出を行う。検査対象物としては、歯車などの外周部(側面)に垂直な面を持つ対象物が好ましい。また、高輝度画素の画素数は、良品とは異なった傾きの面の大きさに比例するため、当該高輝度画素の画素数に基づいて欠けの大きさを算出するようにしてもよい。

【0011】本実施形態では、図4に示すように、測定対象物23の側面より検出領域の上端付近に検出面と平行にスリット状のレーザ光等を照射する。欠陥が無い場合には、観測方向15へ反射する反射光量18Bはごくわずかであるが、欠陥により、傾きを持った新たな面が生じると、観測方向15への反射光量18Aが増加する。この反射光量18Aを高輝度画素として抽出することで、安定した欠陥の検出が可能となる。高輝度画素の抽出は、測定対象物の周囲の輝度が小さく、暗い場合には単純に所定のしきい値で二値化することで良好に行えるが、測定対象物の周囲も明るい場合には、良品画像との差分を取るようにするとよい。すると、測定対象物の他の部分と一致しない高輝度部分のみを良好に抽出することができる。

【0012】次に、測定対象物を撮像する環境にて外乱光が多い場合や、また、測定対象物が金属であるなど反射率が高い表面を有する場合の対策を説明する。再度図1を参照すると、図1に示す例では、撮像工程S3の前に、測定対象物から入射される光の内計測光の帯域以外の帯域の光を遮断するフィルタ工程S2を備えている。このフィルタ工程S2は、図2に示す例では、CCDカメラ3Aのレンズの先に取り付けられた光学的バンドパスフィルタを使用すると、フィルタ工程が行われる。計測光の帯域以外の帯域の光を遮断する光学的バンドパスフィルタ1を設けて撮像すると、計測光のみを撮像することができ、すると、外乱光が多い環境での計測であっても、安定して欠けを検出することができる。

【0013】また、バンドパスフィルタ1を用いると、良品の画像との差分を求める処理が不要となる。すなわち、平面の面のみを有する良品を検査対象物として、CCDカメラ3に使用するレーザ光源の波長に合わせた光学的バンドパスフィルタを設置すると、レーザ光により照明された箇所のみが撮像され、他の照明による光が入射しない。すると、欠けに応じた高輝度部分のみが輝

度を有する画像が得られる。バンドパスフィルタ1を用いると、良品との比較が不要となるため、検査対象の厳密な位置決めも不要となる。

【0014】

【実施例】図5は本発明の一実施例の構成を示す説明図である。図5に示す例では、欠陥検出装置は、CCDカメラ3と、このCCDカメラ3のレンズ先端に配置されたバンドパスフィルタ1と、CCDカメラ3の撮像方向と直交する平面に撮像手段を中心としてリング状に配置された複数のレーザダイオードを有するLEDリング照明と、CCDカメラ3から基線長離れたところに立体計測用光源40とこの立体計測用光源40からのレーザ光を走査する立体計測用ガルバノスキャナ41と、測定対象物の側面に計測光としてのスリット光を照射する光源18と、この光源18からのスリット状のレーザ光を走査するガルバノスキャナ19とを備えている。レーザ光（スリット光）と、LEDリング照明の照明光4aと、バンドパスフィルタ1aの必要なスペクトル特性を図5（B）に示す。本実施例では、レーザ光は、立体計測用のスリット光と欠け検出用のスリット光とは同一の波長としている。また、上述した実施形態にて「画像」と呼んだものを、ここでは「欠け検出用画像」という。

【0015】図6（A）に示すように、本実施形態で使用する半導体レーザのピーク波長は、682.75[nm]である。そして、図6（B）に示すように、バンドパスフィルタ1の中心波長は683[nm]であり、半値幅は11[nm]、透過率は84.8%である。また、図7に示すように、LEDスペクトル特性は、中心波長は約660[nm]で、半値幅は約50[nm]である。

【0016】望ましくは、LEDリング照明4の輝度が最も強い帯域のほぼ中心付近にレーザ光源の共振波長を一致させ、バンドパスフィルタ1は半値幅が十分に狭く、光源18、40のレーザ光の波長が十分に通過できる特性のものを採用する。

【0017】図7に示すLEDと蛍光灯のスペクトルから判るように、使用しているレーザの波長付近では蛍光灯に比べてLEDはそのエネルギー比が2倍以上となっている。しかも、実際に使用する場合には対象物の近くから強いLED照明をあてるため、周囲にある蛍光灯との強度比は10倍以上となっている。その中で半導体レーザも十分に通るフィルタをつけているため、欠け検出用、二次元および三次元のデータを外乱光の影響を受けずに測定することが実際に可能となっている。

【0018】図5に示す例では、CCDカメラ1台で、安定して歯車等の測定対象物の欠け検出画像、濃淡画像および三次元形状を入力でき、さらに遮光板などを全く必要とせず欠けの有無、歯数、直径、ボス面の凹凸形状を得ることができる。

【0019】このように、LEDリング照明と、そのスペクトルのほぼ中心付近の波長成分を持つレーザスリッ

ト光と、それら両方にラップする帯域を限定したバンドパスフィルタをレンズ先端に設けたため、LEDリング照明により均一な明るさの濃淡画像を、蛍光灯や白熱球などの広いスペクトル成分を持つ照明と比較して少ない消費電力で得ることができ、さらに、バンドパスフィルタの効果により周囲の蛍光灯などの影響を全く受けず、従って、生産現場への設置が容易となる。また、光の高周波成分などの乱反射光がフィルタによりカットされ、さらに単色の照明であるため、金属面での特徴が良好に現れる。

【0020】そして、レーザ光の波長は透過するため、LED照明をオフにしてレーザ光を走査すれば安定して三次元形状を取込むことができ、また、カメラが1台であるため、同じ画角の濃淡画像と距離画像とを得ることができ、このため、画像処理が容易となる。

【0021】この三種類のデータを併用することにより、図3（A）に示す良品に対して、図3（B）に示すような欠けが生じた場合には濃淡画像や距離画像に基づいて欠けを検出し、また、図3（C）に示すような欠けが生じた場合には欠け検出用画像に基づいて良好に安定して検出することができる。

【0022】図8はスプロケットの歯先先端部の欠けの検出例を示す説明図である。図8に示す例では、図中左側から測定対象物へ向けて計測光（スリット光）を照射し、図面の法線方向から撮像した。図8（A）は、バンドパスフィルタを設けない構成にて撮像したスリット光照射生画像である。図8（A）に示す例では、スプロケットの左側の刃先部分に高輝度部分が生じている。しかし、この歯車の右側の輝度も高く、所定のしきい値で二値化することでは高輝度部分を抽出することができない。従って、この図8（A）に示す例では、良品の画像との差分を取ることで、高輝度部分を抽出する。

【0023】図8（B）はバンドパスフィルタを設けて撮像した例を示す。スリット光を側面から照明し、バンドパスフィルタを通して撮影を行うと、図8（B）に示すように欠陥部のみが明るくなった画像を得ることができる。これにより、その後の処理は明るく光った領域の大きさを調べるだけで良く、良品画像との差分を求めるなどの画像処理が不要となり、このため、測定対象物の厳密な位置決めが不要で、撮影後の画像処理の簡素化・高速化が可能となる。また、検出にバンドパスフィルタを用いることにより、環境光の影響を排除することができる。

【0024】図8に示す例では、照明を一方向から行っているため、歯車など円筒形状物の側面全体を検査するには、検査対象物を回転させる機構が必要となる。これに対し、図9に示すように、4方向またはリング状に全周方向から照明することで、回転機構の廃止が可能となる。この例では、測定対象物の欠けを検出する複数の面に略垂直な方向から計測光を照射する照射手段を設け

る。図9(A)に示す例では、符号15a乃至15eの4つの方向からそれぞれ計測光を照射する照射手段を配置する。図9(B)に示す例では、15a乃至15hの8つの方向から計測光を照射する。これらの照射は同時に行い、1枚の欠け検出用画像を得ることで、測定対象物外周のすべての欠陥の検出を行うことができる。

【0025】また、歯車など段差がある平行面を有する対象物では、それぞれの面に合わせて異なる高さより照明を行うと、異なる検査ポイントを動時に検査することが可能となる。

【0026】上述したように本実施形態によると、検査対象物の側面より検出面と平行にスリット照明を投光するため、欠陥部だけが明るく照明され、これにより、安定した検出が可能となる。また、スリット光源にレーザを用い、レーザ光の波長に合わせた光学式のバンドパスフィルタをカメラのレンズ部に組み込むと、レーザ光により照明された場所(欠陥)のみの撮影が可能となり、良品との比較が不要となるため、厳密な位置決めが不要となる。また、バンドパスフィルタによりレーザ光と異なる波長の環境光が遮断されるため、外乱の影響を受けづら

【0027】さらに、検査対象に対して4方向またはそれ以上の数の方向から照明を行う例では、検査対象物の側面の全周の検査を一度に行うことができ、検査対象を回転させる必要がなくなる。また、検査対象の側面より異なる高さの検査ポイントに対して、検出面と平行にスリット照明を投光する例では、異なる検査ポイントの同時検査が可能となる。

【0028】

【発明の効果】本発明は以上のように構成され機能するので、これによると、測定対象物の側面の平面にて欠けが生じていると、当該欠け部分で計測光が上方へ反射し、撮像工程にて、この欠けにて反射した計測光が撮像されるため、周囲の輝度よりも高い輝度の領域が生じ、従って、撮像した画像に高輝度画素がある場合には、測定対象物の側面の平面の一部に欠けが生じたと判定することができ、すると、平面を撮像したのみでは外形の変化を計測しづらい測定対象物の欠けを安定して計測することができる、という従来にない優れた欠陥を検出する方法及び装置を提供することができる。

【図面の簡単な説明】

【図1】本発明による欠陥計測方法の実施形態の構成を示すフローチャートである。

【図2】図2(A)は本発明による欠陥計測装置の実施形態の構成を示す説明図であり、図2(B)は欠け部分により生じる高輝度画素を示す図である。

【図3】測定対象物に生じる欠けの例を示す説明図であり、図3(A)は良品を示す図で、図3(B)は刃先の全体が欠けた場合の例を示す図で、図3(C)は刃先に良品とは異なる面を生じさせる欠けの例を示す図である。

【図4】欠けと計測光の反射の関係を示す説明図であり、図4(A)は良品の場合の反射の例を示す図で、図4(B)は欠けが生じた場合の反射の例を示す図である。

【図5】本発明の一実施例の構成を示す説明図であり、図5(A)は各構成の配置例を示す図で、図5(B)は計測光と照射光とバンドパスフィルタとのスペクトル特性を示す図である。

【図6】図6(A)は図5に示すレーザ光(計測光)の波長の一例を示すスペクトル図であり、図6(B)はバンドパスフィルタのスペクトル特性を示す図である。

【図7】図5に示す照射光の一例としての赤LEDおよび他の光のスペクトルを示すスペクトル図である。

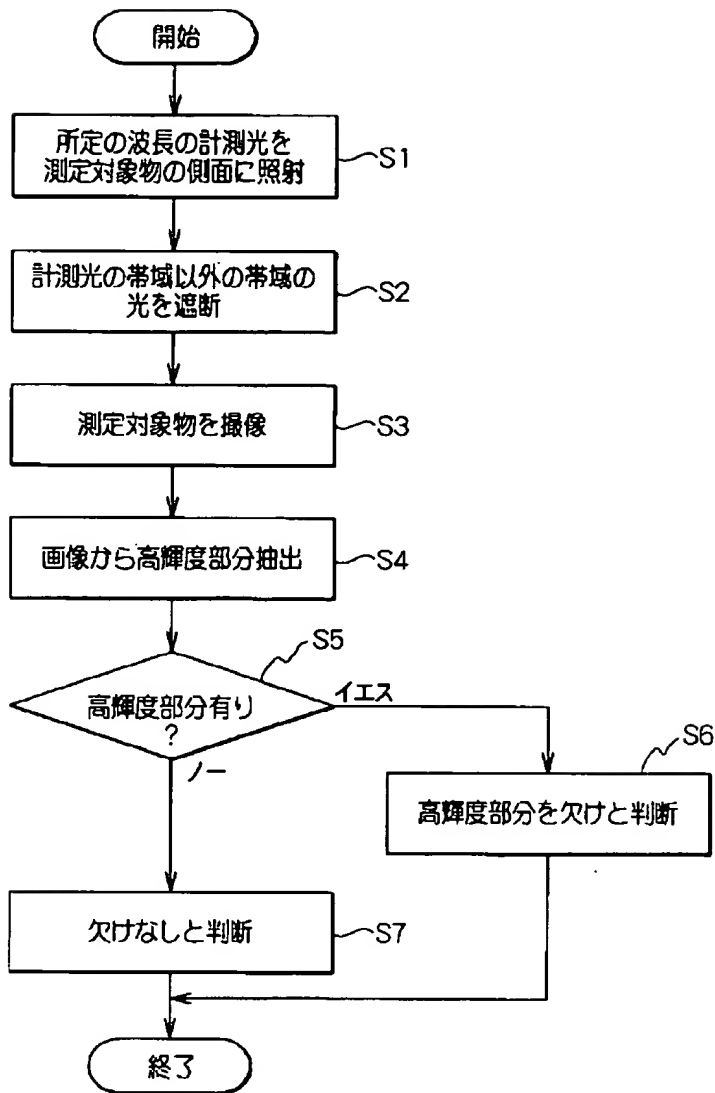
【図8】図5に示す構成にて撮像した欠け検出用画像の一例を示す説明図であり、図8(A)はバンドパスフィルタを設けない場合の例を示す図で、図8(B)はバンドパスフィルタを設けた場合の例を示す図である。

【図9】図5に示す構成に対して照射手段を複数設けた場合の配置例を示す説明図であり、図9(A)は4方向から照射光を照射するときの照射手段の配置を示し、図9(B)は8方向から照射光を照射するときの照射手段の配置を示す。

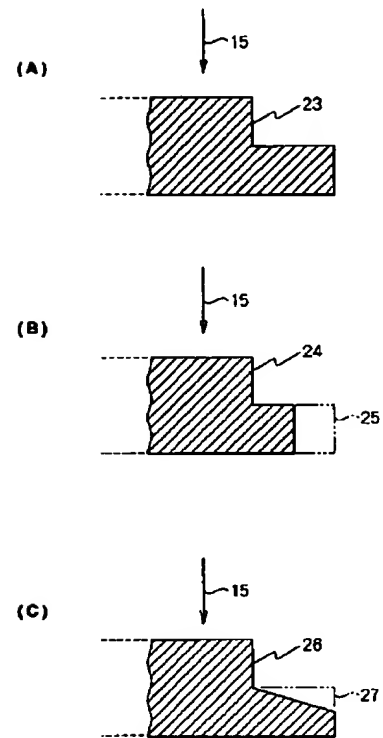
【符号の説明】

- 1 バンドパスフィルタ
- 3 CCDカメラ
- 10 画像処理手段
- 11 高輝度部分抽出部
- 12 欠け判定部
- 18 光源
- 19 ガルバノスキャナ

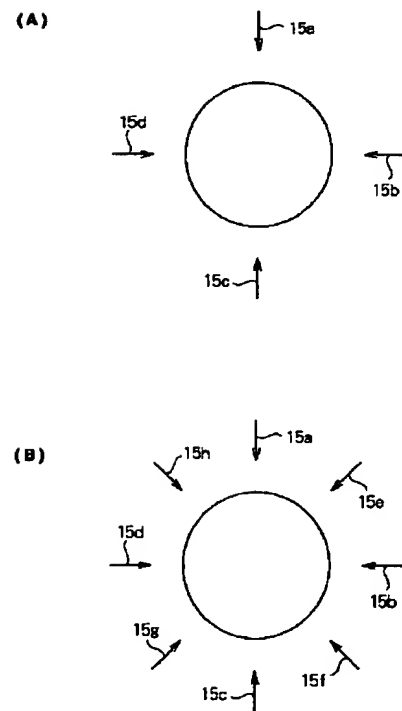
【図1】



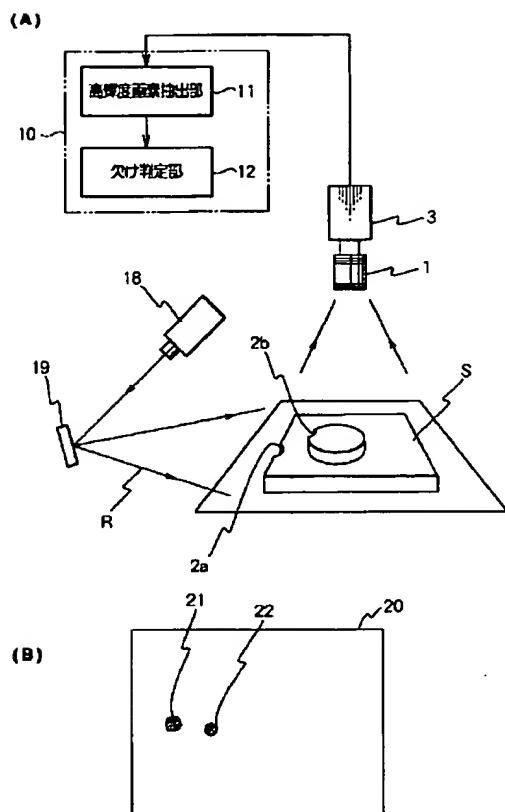
【図3】



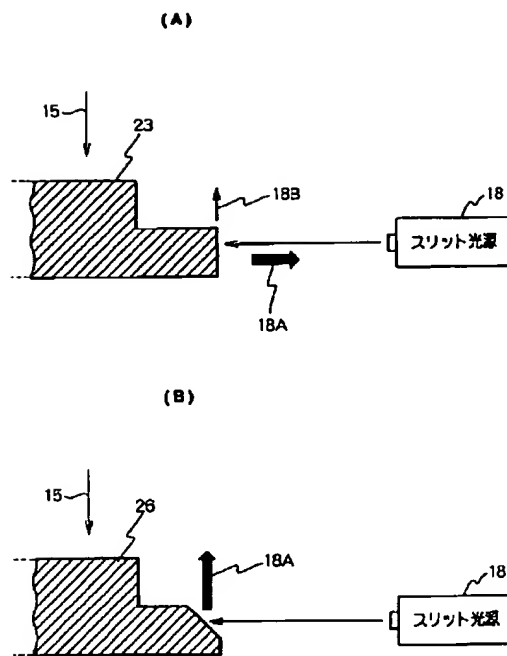
【図9】



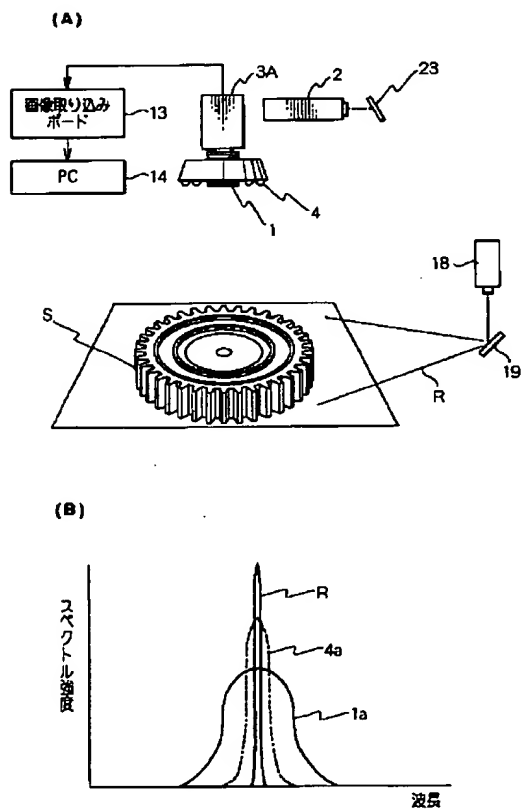
【図2】



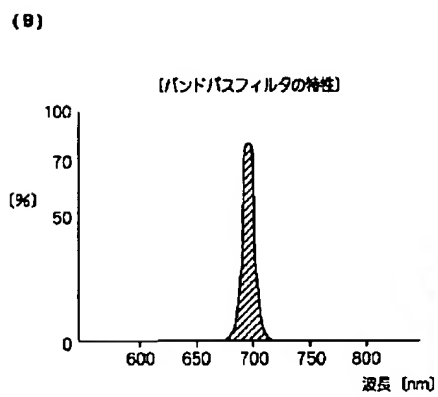
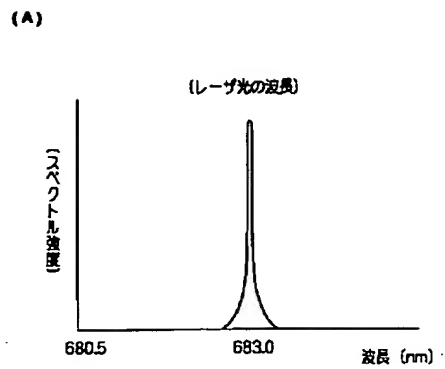
【図4】



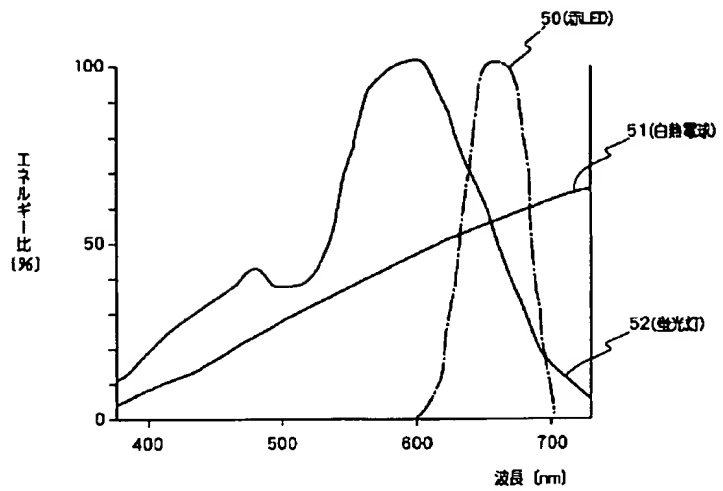
【図5】



【図6】

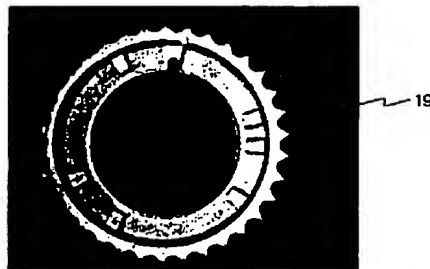


【図7】



【図8】

(A)



(B)



フロントページの続き

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